Like it or not:

Stefan Schmid (TU Berlin & T-Labs)

Like it or not:

The world becomes virtualized, software-defined, and distributed

Stefan Schmid (TU Berlin & T-Labs)


Internet Trends: Virtualized…

Virtualization: Main innovation motor in today's Internet

- It's about isolation (of performance, resources, …)
- Benefits: resource sharing, elastic computing, flexibility, fault-tolerance

Internet Trends: Virtualized…

So far: Server Virtualization

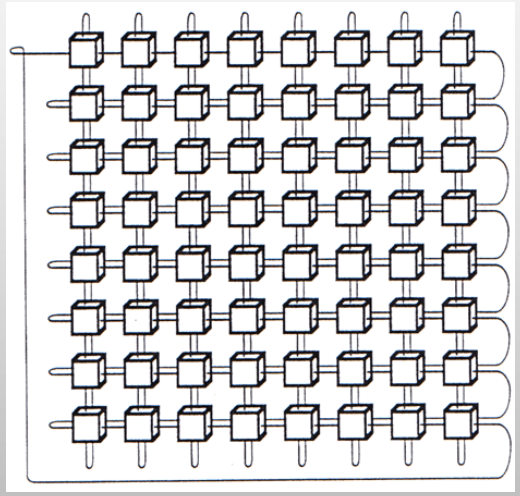
- Revamped server business over last decade
- Cloud, datacenter, …: virtual machines only

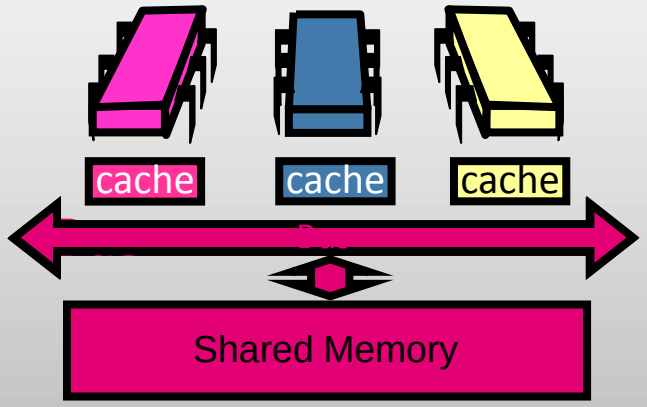
Next: Link Virtualization

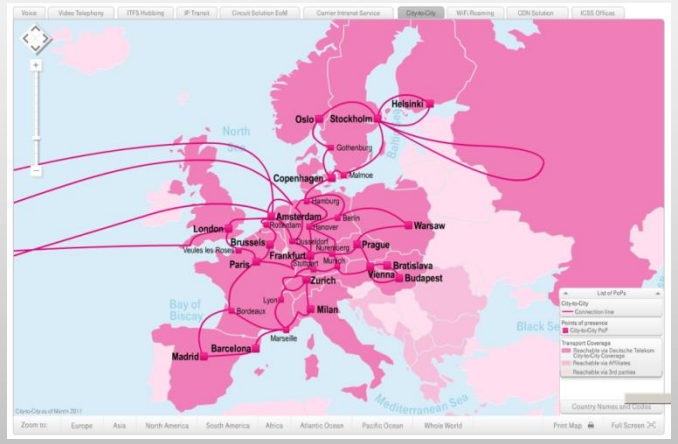
- Cloud resources pointless if they cannot be accessed!
- Performance guarantees, flexible management (latency-critical vs delay-tolerant), …
- E.g., network hungry applications in datacenters (Map/Reduce Shuffle)
- E.g., submitting Sandra's research data …

Internet Trends: … Distributed… (1)

small/synchronous/... wide-area/decoupled/...







E.g., your graphic card: tiny graphical processing units (GPUs) and specialized devices, in which large arrays of **simple processors** work in lock-step (PRAM)

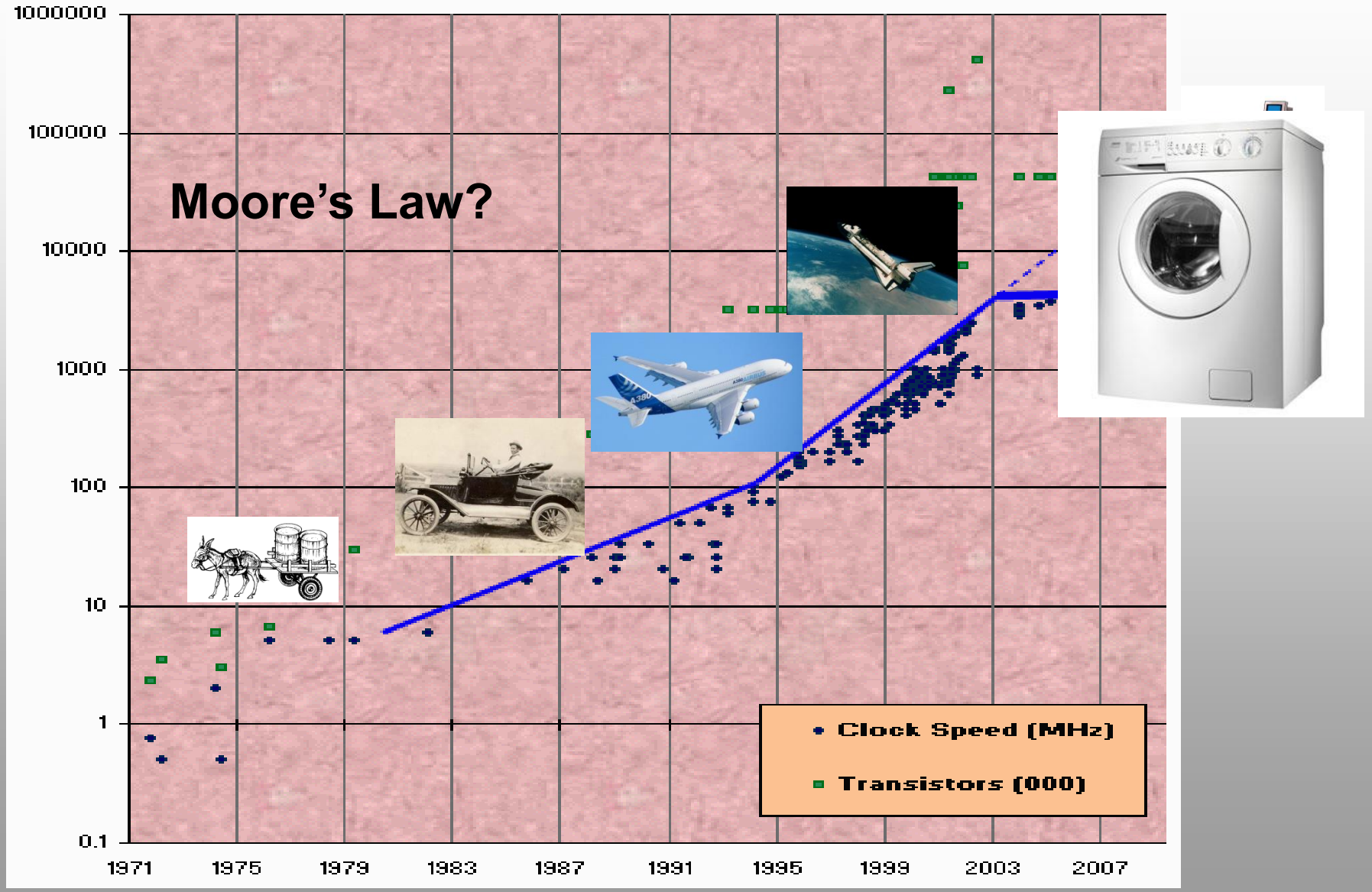
E.g., your laptop: multi-threaded + multi-core servers/desktops with **shared memory for communication**.

E.g., your cloud: **distributed clouds**, loosely-coupled **peer-to-peer** systems with message passing communication (astro, molecule, …), …

Connected!

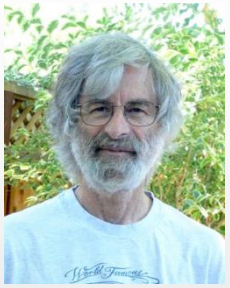
Why? Clock speed cannot be increased arbitrarily, (thermal problems, performance gap between memory and CPU, ...) , a lot of resources out there, closer to eyeballs (Amazon/Bing/Google studies)…

Internet Trends: … Distributed… (2)

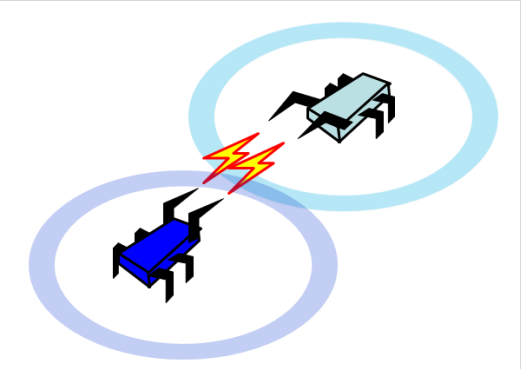


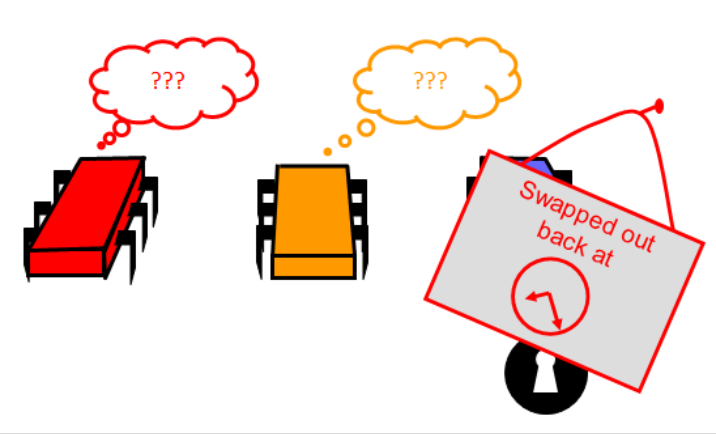
Internet Trends: … Distributed… (3)

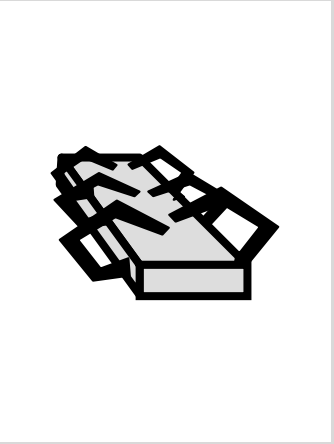
"You know you have a distributed system when the crash of a computer you've never heard of stops you from getting any work done." (Leslie Lamport)



Distributed systems are complex: communication, concurrent, failures, …







Internet Trends: … Distributed… (4)

Limitations:

- Some problems cannot be solved at all in distributed settings (e.g., consensus under failures)
- There are inherent limits to the speedup

Amdahl's Law

$$S = \frac{1}{\underbrace{1-p}_{\text{serial part}} + \underbrace{p/n}_{\text{parallel part}}}$$

S = speedup

p = fraction of work that can be done in parallel

n = number of processors

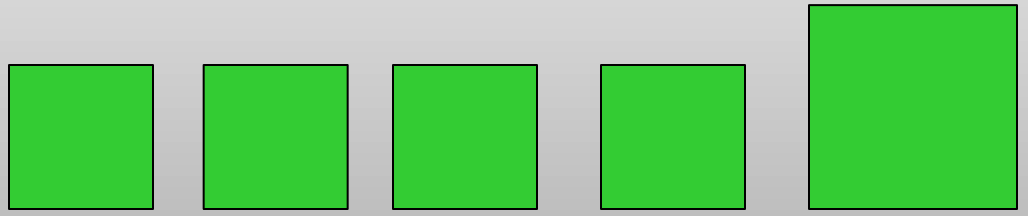
Try to minimize serial part!

Internet Trends: … Distributed… (5)

Example: 5 friends want to paint new apartment, with 5 rooms

Speed-up: 5 times faster than alone!

What if last room is twice as large?

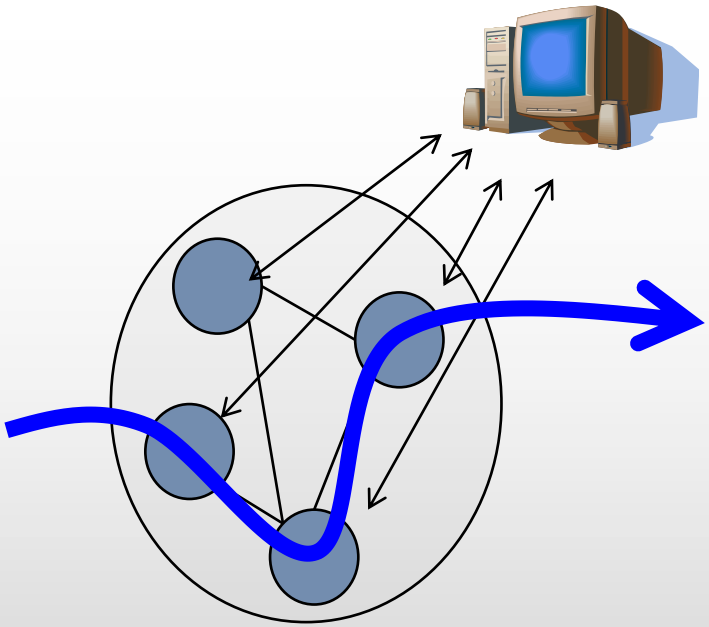


- Assigning one painter to one room, 5/6 of the work can be performed in parallel.
- Parallel execution time = (1-5/6)+1/6 = 1/6+1/6 = 2/6 = 1/3. Only 3 times faster!
- Would be better to parallelize painting of last room also!

Internet Trends: … Software-Defined.

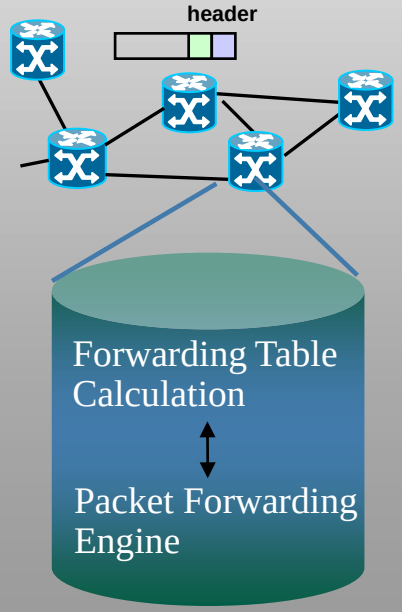
Flexible Software Control:

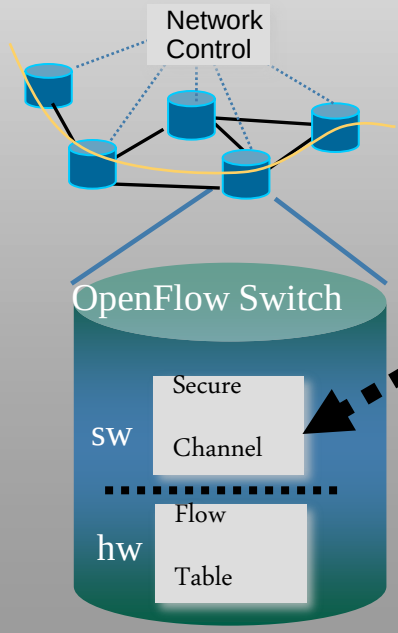
- "Open" and standard interface to manage hardware; per flow not per packet!
- Software-defined networking: logically centralized software control of forwarding paths
- Traffic engineering (load-balancing), network management and control, …
- Layer 2-4, tagging (application-aware, e.g., for hospital, Skype, …), fast innovation (software!), …
- E.g., Google G-Scale network



local forwarding decision per **packet**

Traditional Switch

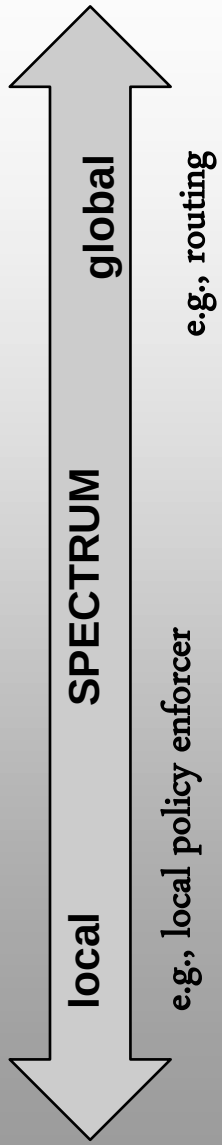




per **flow** switching

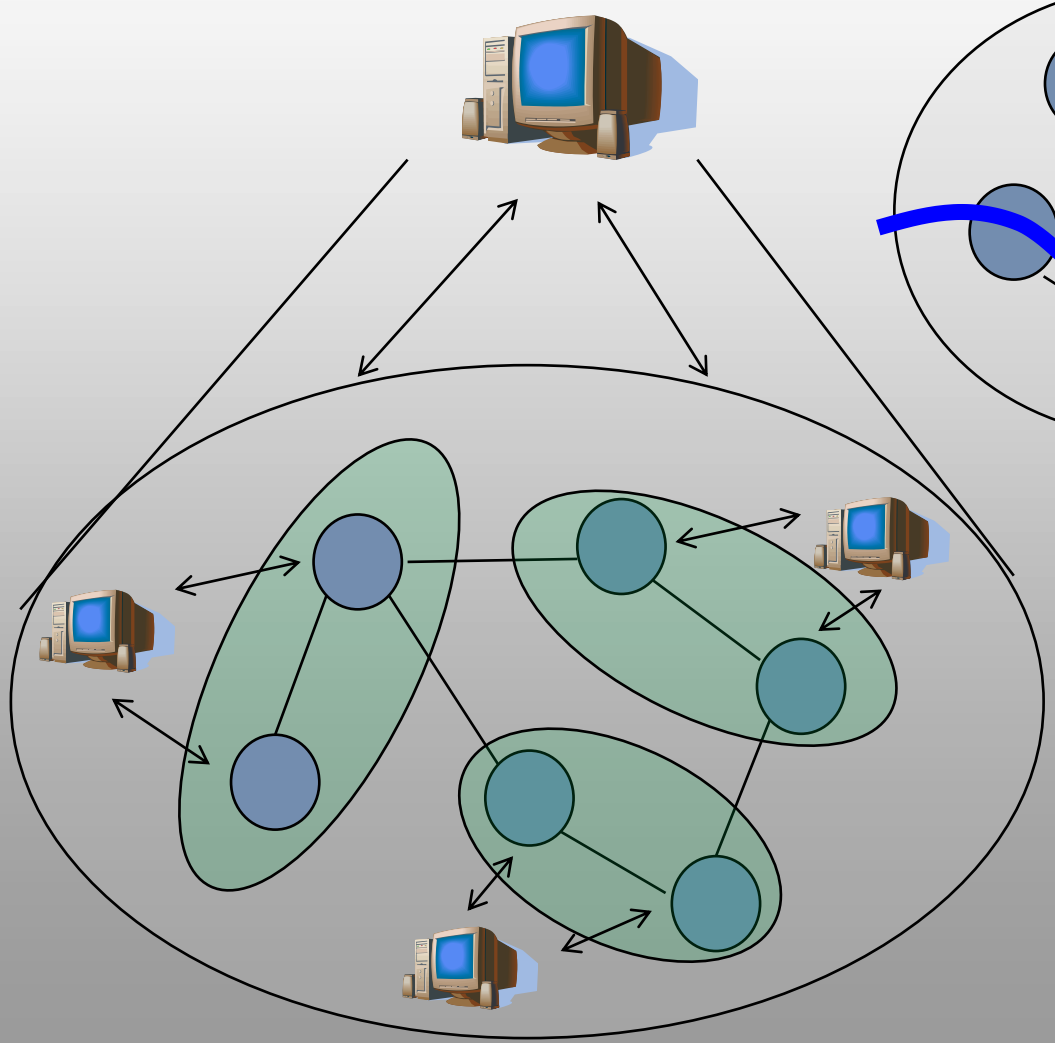
OpenFlow Controller

Trends Combined: SDN+Distributed!



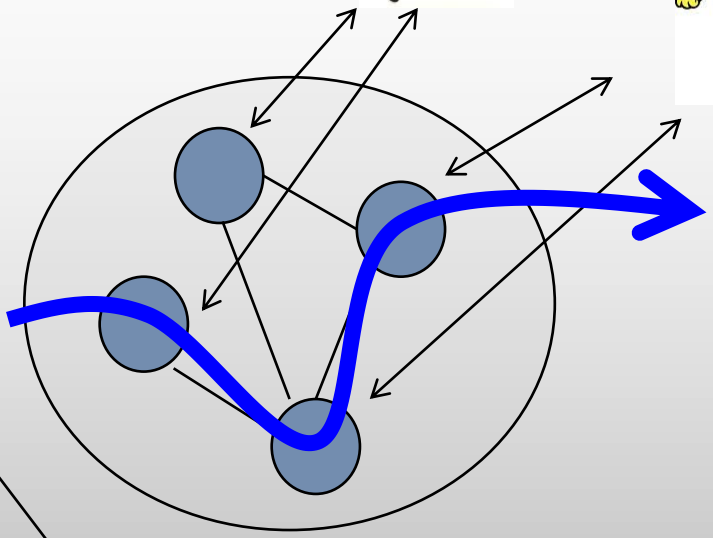
e.g., routing

e.g., local policy enforcer



Alice

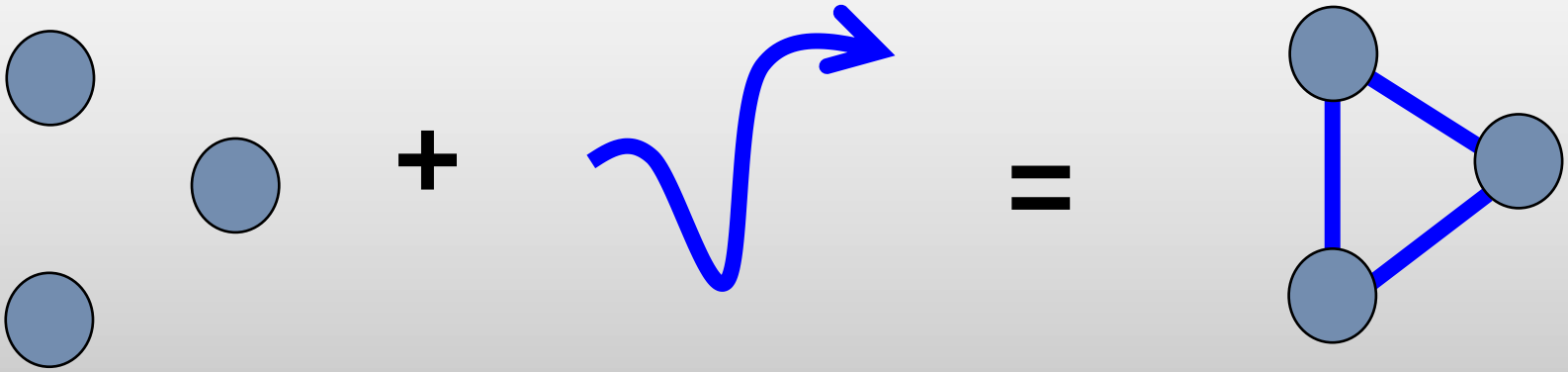
Bob



- Scalability, load-balancing, and robustness
- E.g., handle frequent events close to data path, shield global controllers, ...
- And: multi-authorship of policies

Research Vision: CloudNets

CloudNets: A virtual network connecting virtual cloud resources

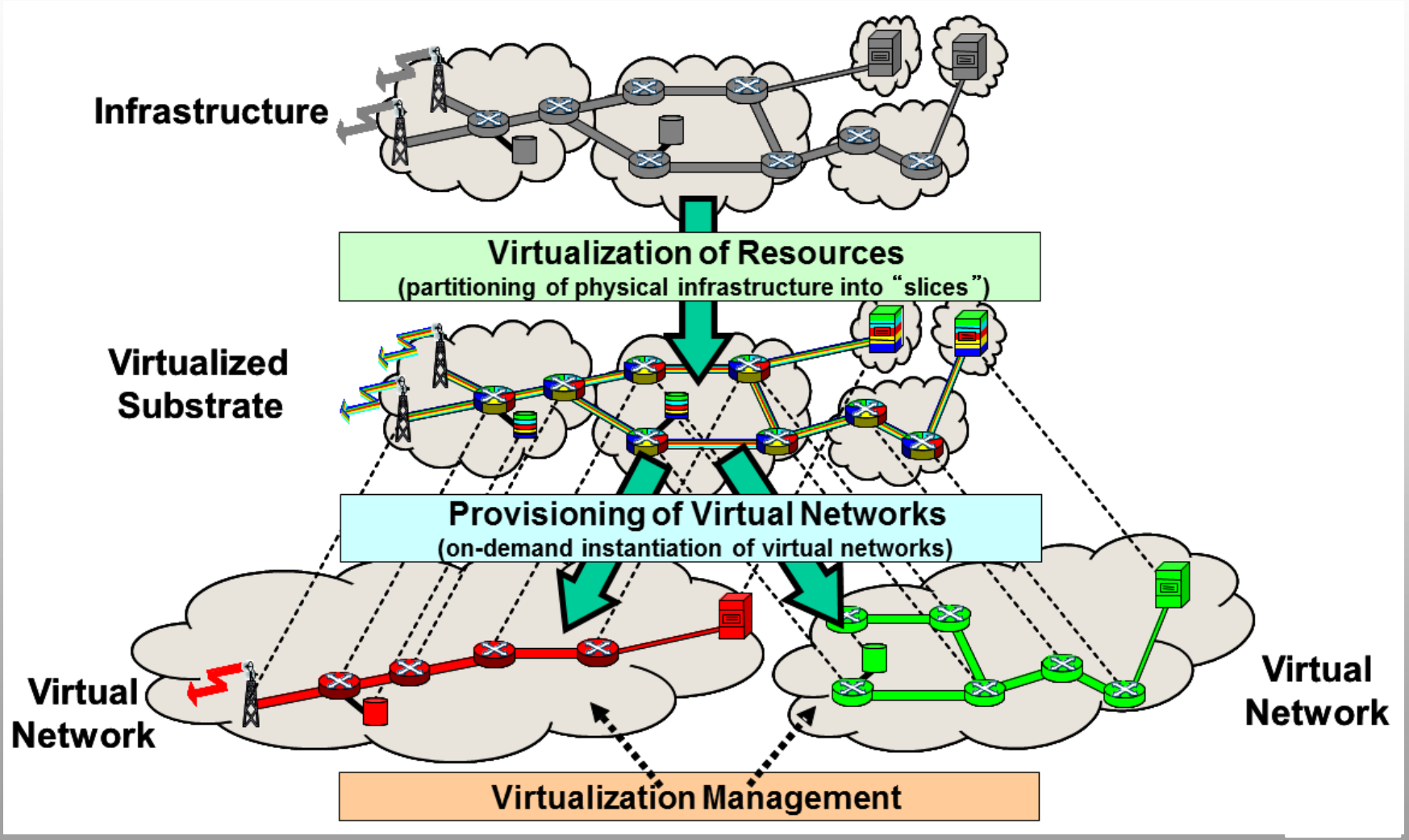


virtual nodes | virtual links | virtual “service”

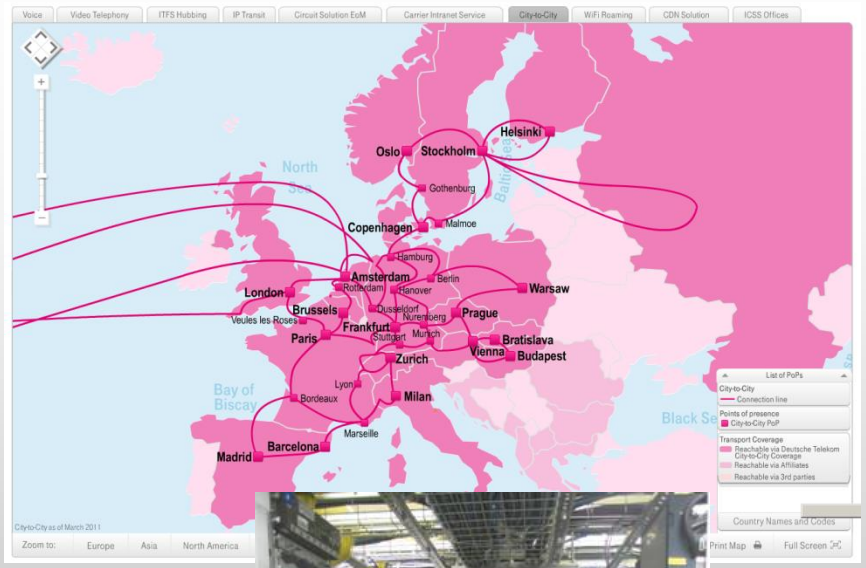
Vision: unify datacenter network with carrier networks with…

Projects: GENI (USA), CHANGE/UNIFY/OFELIA (EU), AKARI (Asia), etc.

Vision: Wide-Area Cloud Networks



Example: Connecting “Nano-Datacenters”



- Resources at POPs, street cabinets, …
- E.g., network monitoring, compute/aggregate smart meter data, …
- New economic roles

Roles in CloudNet Arch.

Service Provider (SP)

(offers services over the top)

API

Virtual Network Operator (VNO)

(operates CloudNet, Layer 3+, innovation)

API

Virtual Network Provider (VNP)

(resource broker, compiles resources)

API

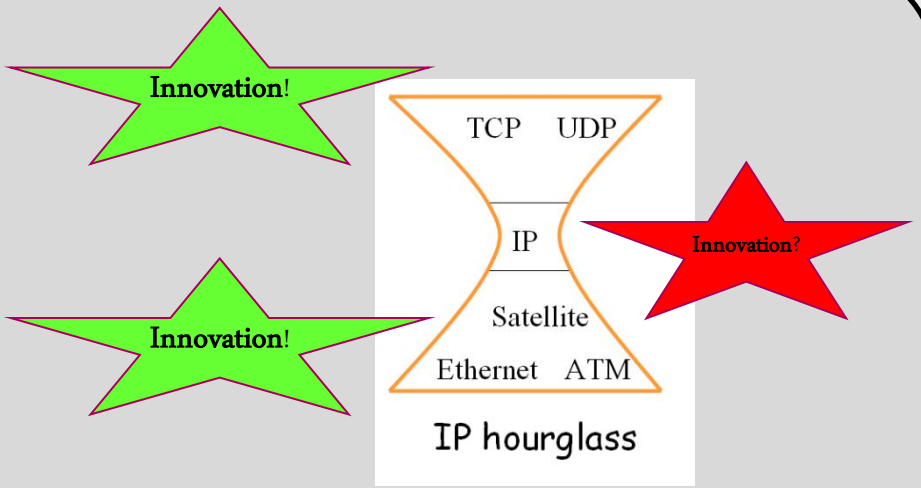
Physical Infrastructure Provider (PIP)

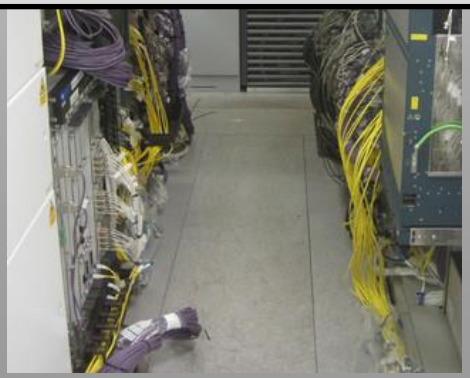
(resource provider, knows infrastructure and demand)

Example: Connecting “Nano-Datacenters”

- Resources at POPs, street cabinets, …
- E.g., network monitoring, compute/aggregate smart meter data, …
- New economic roles

- Innovation in network core: own addressing, routing, intrusion detection, …
- Tailored to application (OSN, HPC, …)
- Today’s Internet: just one out of many virtual networks





API

API

Virtual Network Provider (VNP)

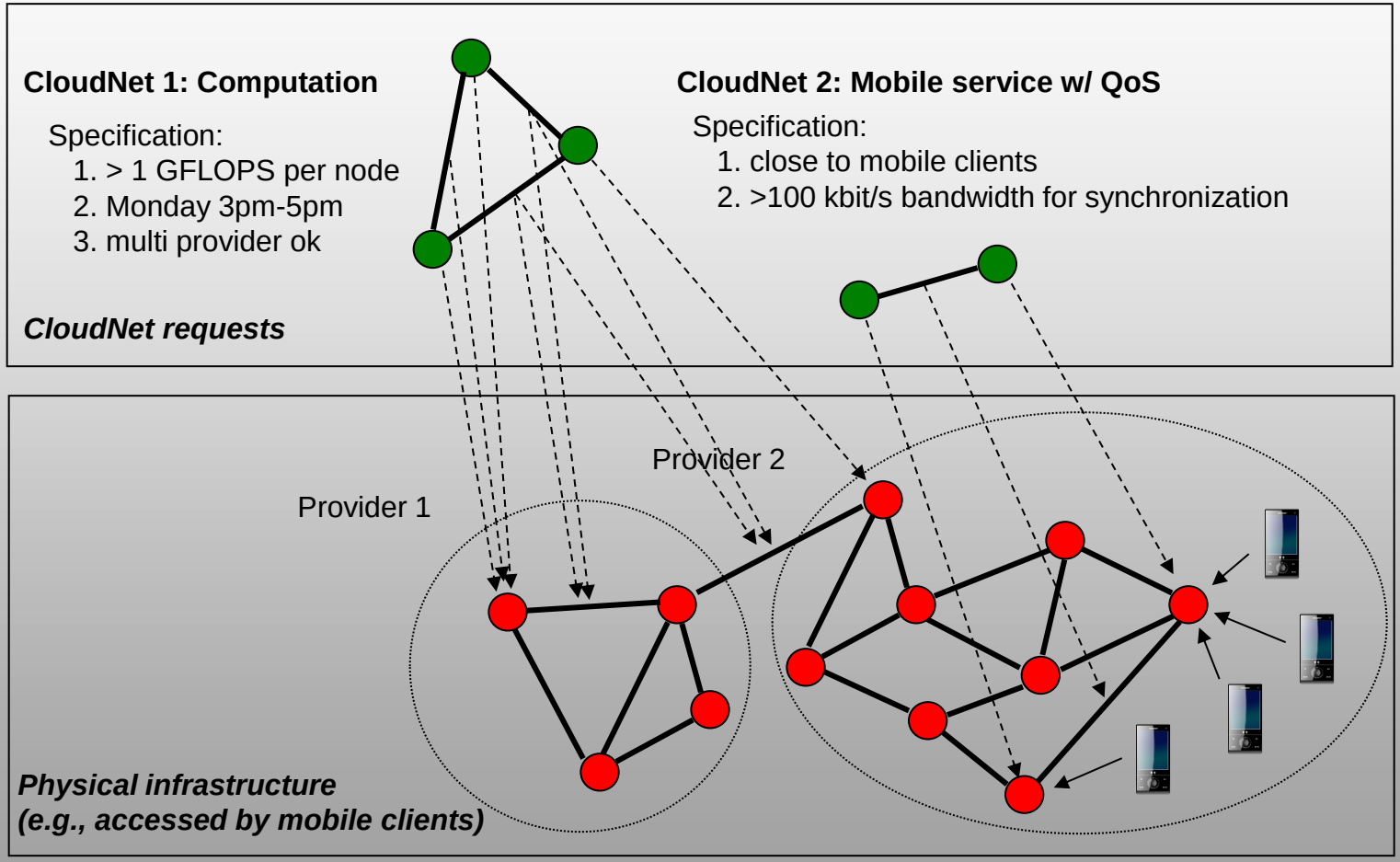
(resource broker, compiles resources)

API

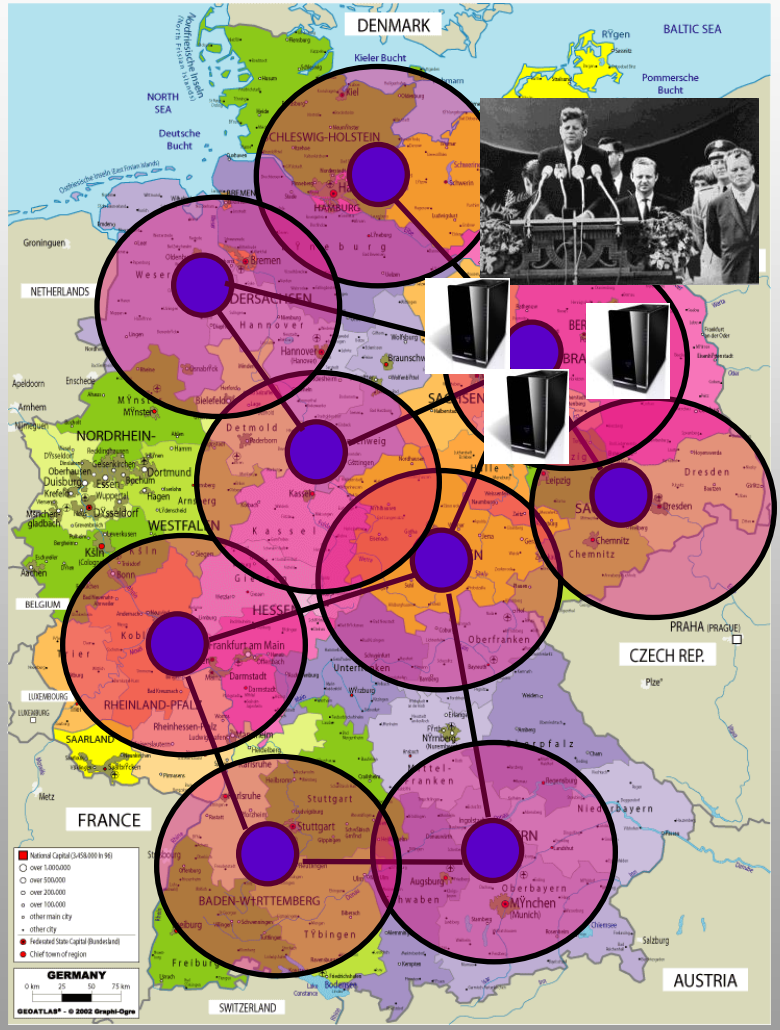
Physical Infrastructure Provider (PIP)

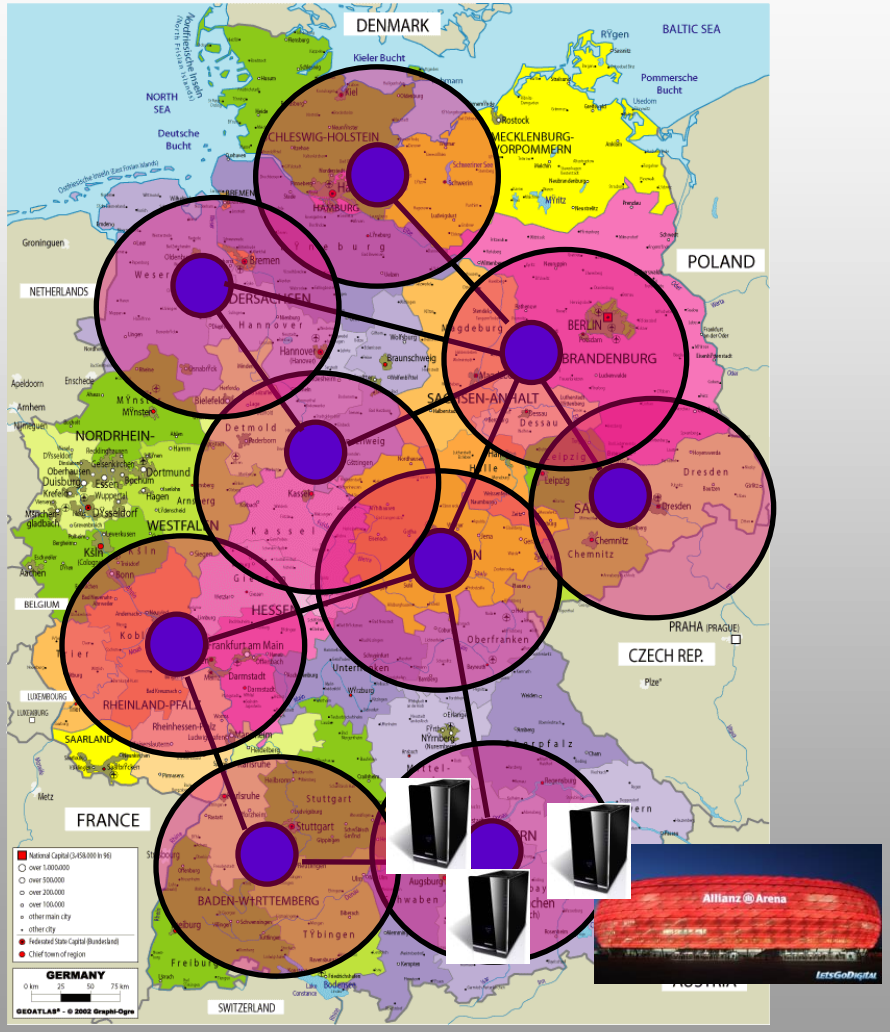
(resource provider, knows infrastructure and demand)

Research Challenge 1: Allocate and Migrate Resources
Or: What to do with the new degrees of freedom?



Research Challenge 1: Allocate and Migrate Resources
Dynamic Allocation and Migration

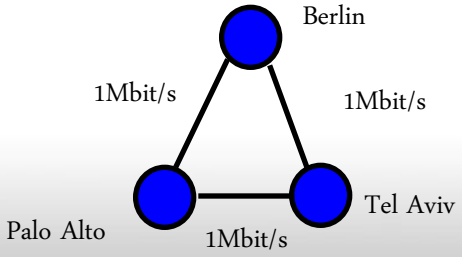




Research Challenge 1: Allocate and Migrate Resources
Use Cases

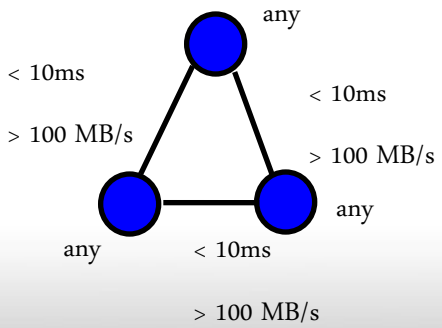
„VPN++“

Goal: *Fully specified CloudNet mapping constraints (e.g., end-points for a **telco**), but with **QoS guarantees** (e.g., bandwidth) along links*



„November 22, 1pm-2pm!“

Datacenters



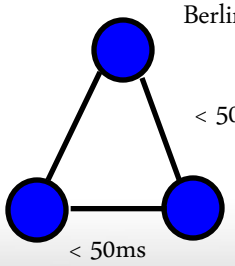
„Guaranteed resources, job deadlines met, no overhead!“

“Network may delay execution: costly for per hour priced VM!”

See, e.g., Octopus system (SIGCOMM 2011)

Spillover/Out-Sourcing

Elastic computing



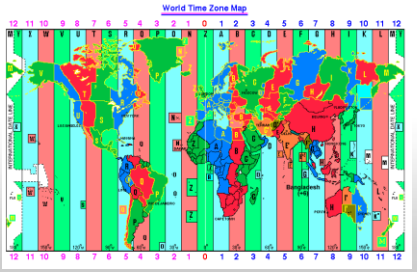
(corporate access network)

„50 TB storage, 10 Tflops computation!“

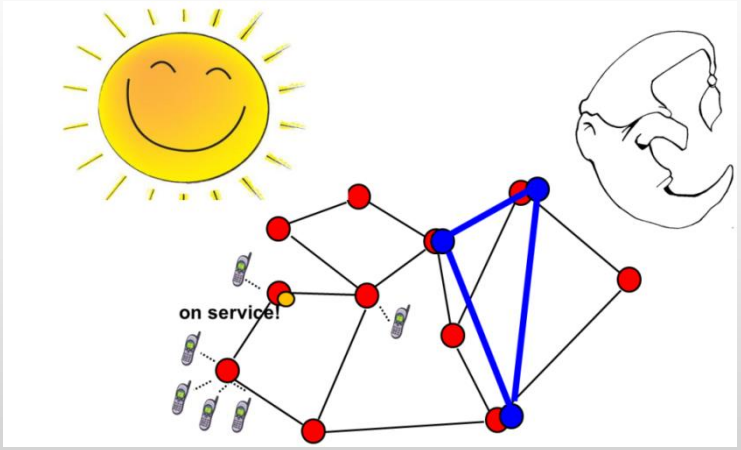
„any European cloud provider (e.g. due to legal issues?)“

Migration / Service Deployment

Goal: *Move with the sun, with the commuters, (QoS) allow for **maintenance**, avoid roaming costs…: e.g., **SAP/game/translator server, small CDN server…***

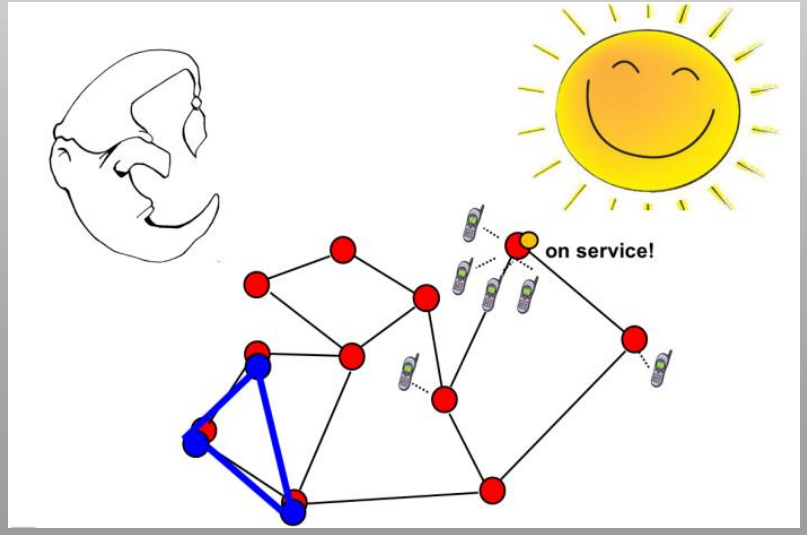


Research Challenge 1: Allocate and Migrate Resources
Migration / Time-of-Day Effects



2 pm in Europe

Latency-resource tradeoffs: move-with-the-sun vs move-with-the-moon?

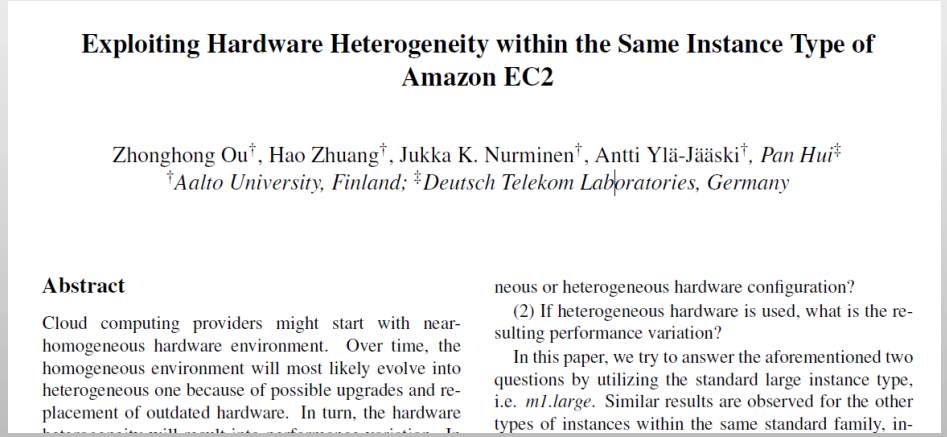


2 pm in Japan

Research Challenge 2: Overhead and Specification
Or: Bare Metal vs Flexibility

- Imperfect illusion: e.g., interference on network, disk, …

- Heterogeneous hardware: “some VMs are more equal than others”



Exploiting Hardware Heterogeneity within the Same Instance Type of Amazon EC2

Zhonghong Ou[†], Hao Zhuang[†], Jukka K. Nurminen[†], Antti Ylä-Jääski[†], *Pan Hui*[‡]
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Abstract

Cloud computing providers might start with near-homogeneous hardware environment. Over time, the homogeneous environment will most likely evolve into heterogeneous one because of possible upgrades and replacement of outdated hardware. In turn, the hardware

neous or heterogeneous hardware configuration?

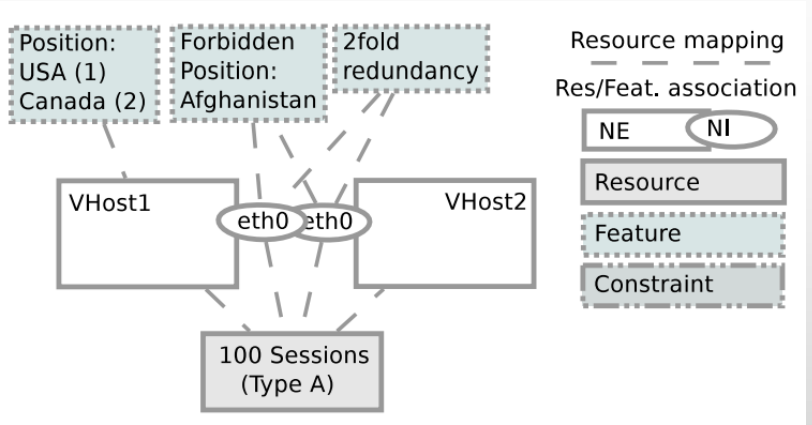
(2) If heterogeneous hardware is used, what is the resulting performance variation?

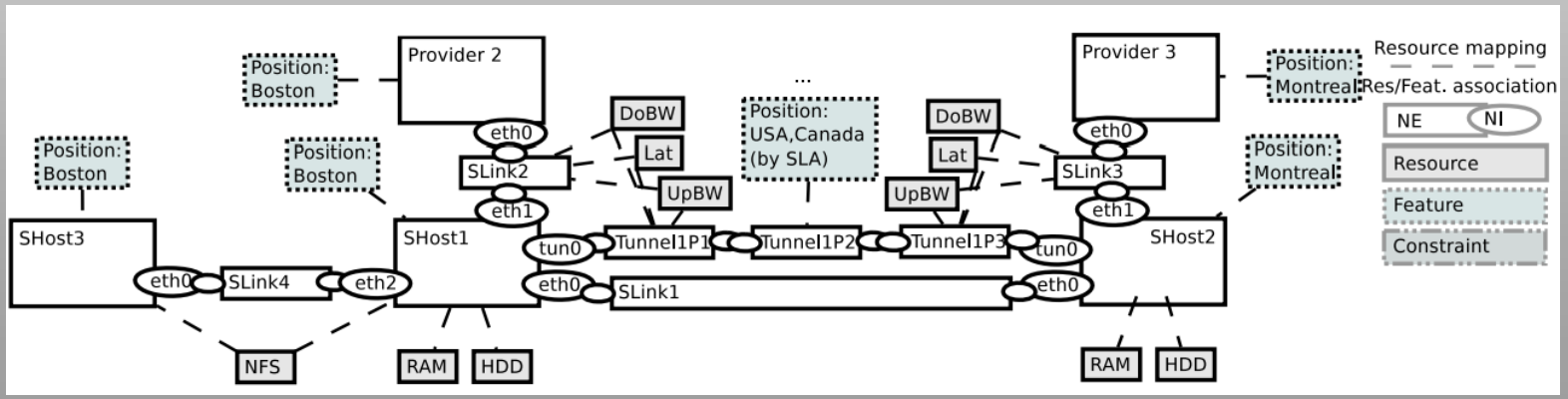
In this paper, we try to answer the aforementioned two questions by utilizing the standard large instance type, i.e. *m1.large*. Similar results are observed for the other types of instances within the same standard family, in-

“We observe a performance variation of up to 60%. By selecting better-performing instances to complete the same task, end-users of Amazon EC2 platform can achieve up to 30% cost saving.”

Research Challenge 2: Overhead and Specification
Or: Bare Metal vs Flexibility

- Virtualization is an overhead
- But it also has advantages
  - Flexible resource allocation
  - Migration
- Provider-Tenant Gap
- Ideally, you are only constrained by specification! General and flexible specification? Across roles?





Research Challenge 3: Security Issues
Or: Get off my cloud!

- **Selfishness:** Migrate Virtual Machine in datacenter
- **Information stealing:** Collocate Virtual Machines in datacenter for side-channel attack
- **Infer weaknesses:** Repeated requests a threat for ISPs

Hey, You, Get Off of My Cloud: Exploring Information Leakage in Third-Party Compute Clouds

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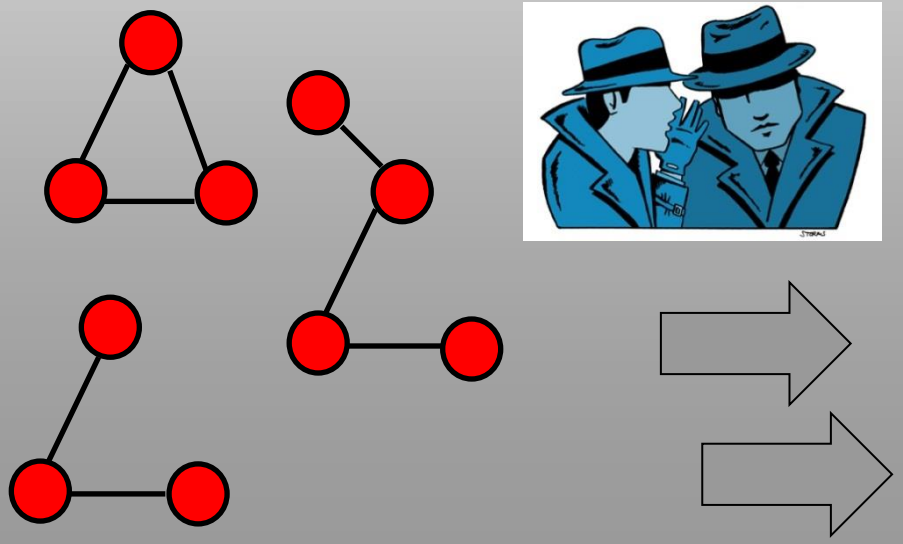
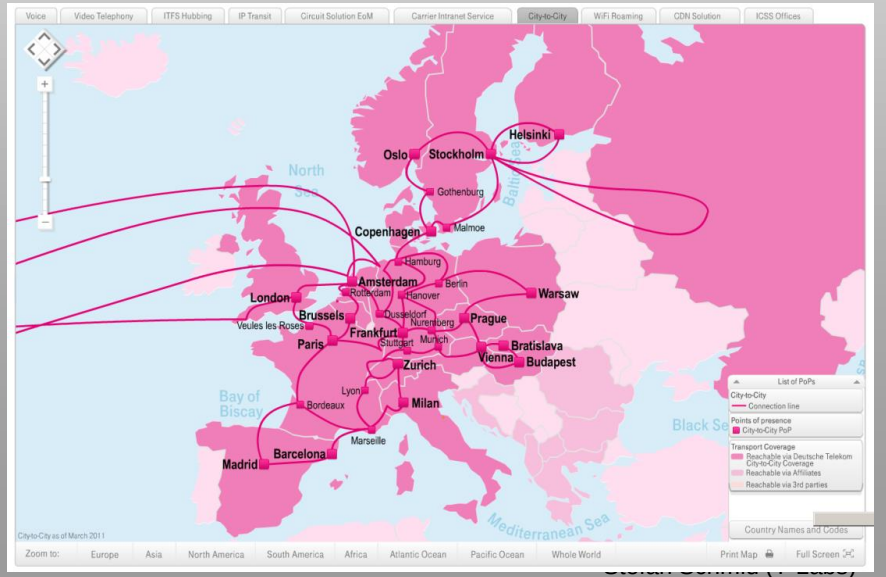
ABSTRACT

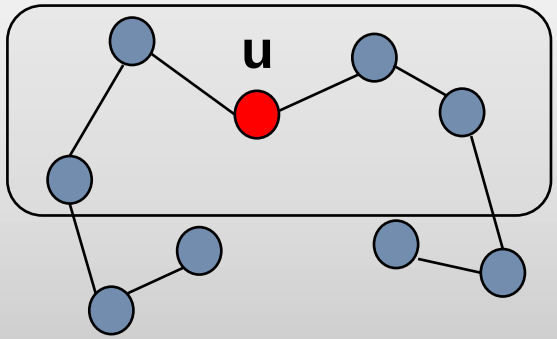
Third-party cloud computing represents the promise of outsourcing as applied to computation. Services, such as Microsoft's Azure and Amazon's EC2, allow users to instantiate virtual machines (VMs) on demand and thus purchase core computing and software capabilities are outsourced *on demand* to shared third-party infrastructure. While this model, exemplified by Amazon's Elastic Compute Cloud (EC2) [5], Microsoft's Azure Service Platform [20], and Rackspace's Mosso [27] provides a number of advantages — including economies of scale, dynamic provisioning, and low

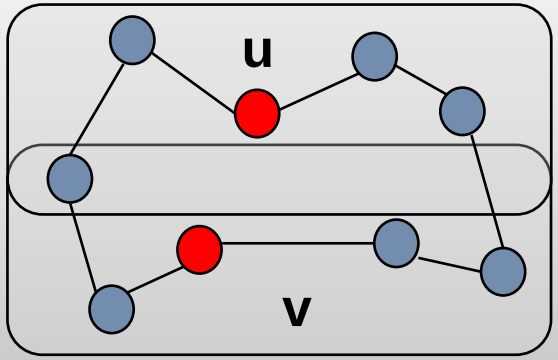


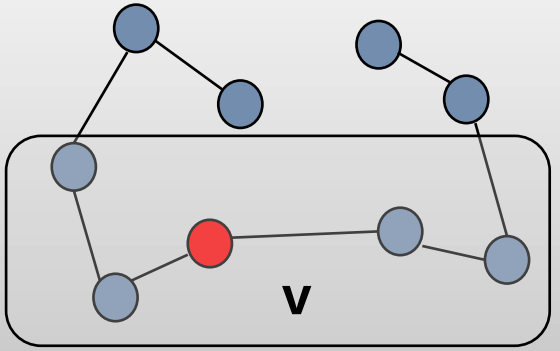


Research Challenge 4: Concurrency / Parallelism
Or: What can be serialized and computed locally?

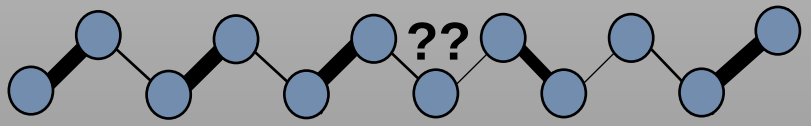
- Some tasks cannot be solved locally: e.g., loop-detection







  - … or load-balancing/matching:



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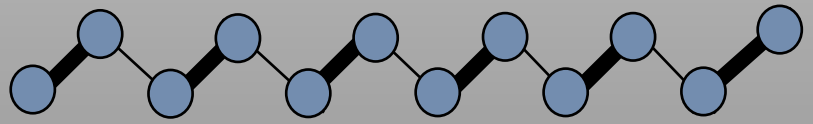

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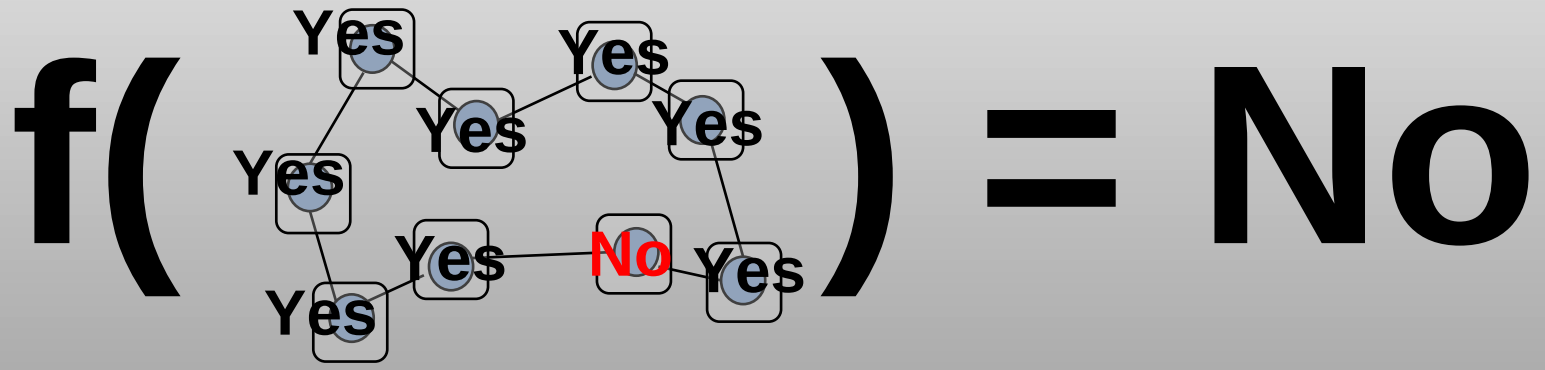
Research Challenge 4: Concurrency / Parallelism
Or: What can be serialized and computed locally?

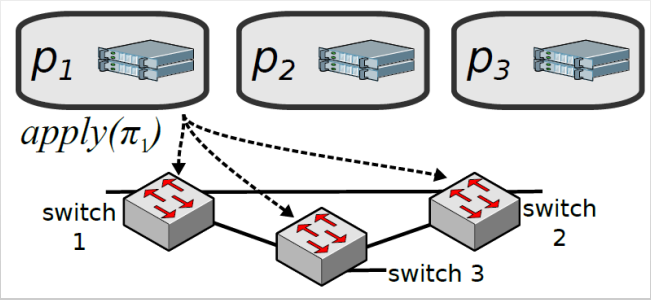
- But many tasks can be solved well approximately
- Or verified with minimal additional information



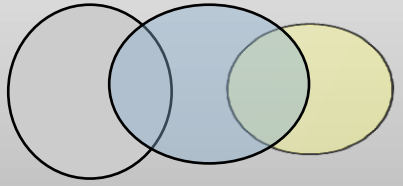
Research Challenge 4: Concurrency / Parallelism
Or: What can be serialized and computed locally?

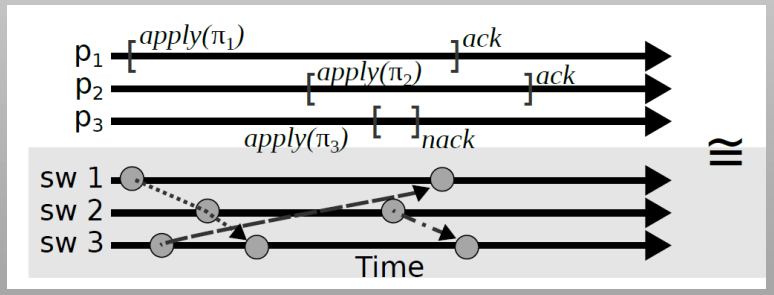
- What about concurrent operation? Want illusion of global serialization!

Example



Three switches, three policies, policy 1 and 2 with independent flow space, policy 3 conflicting:





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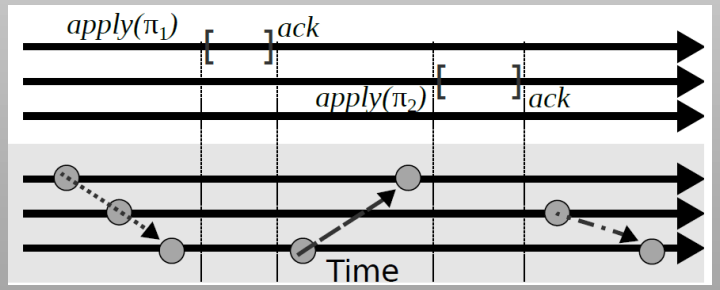
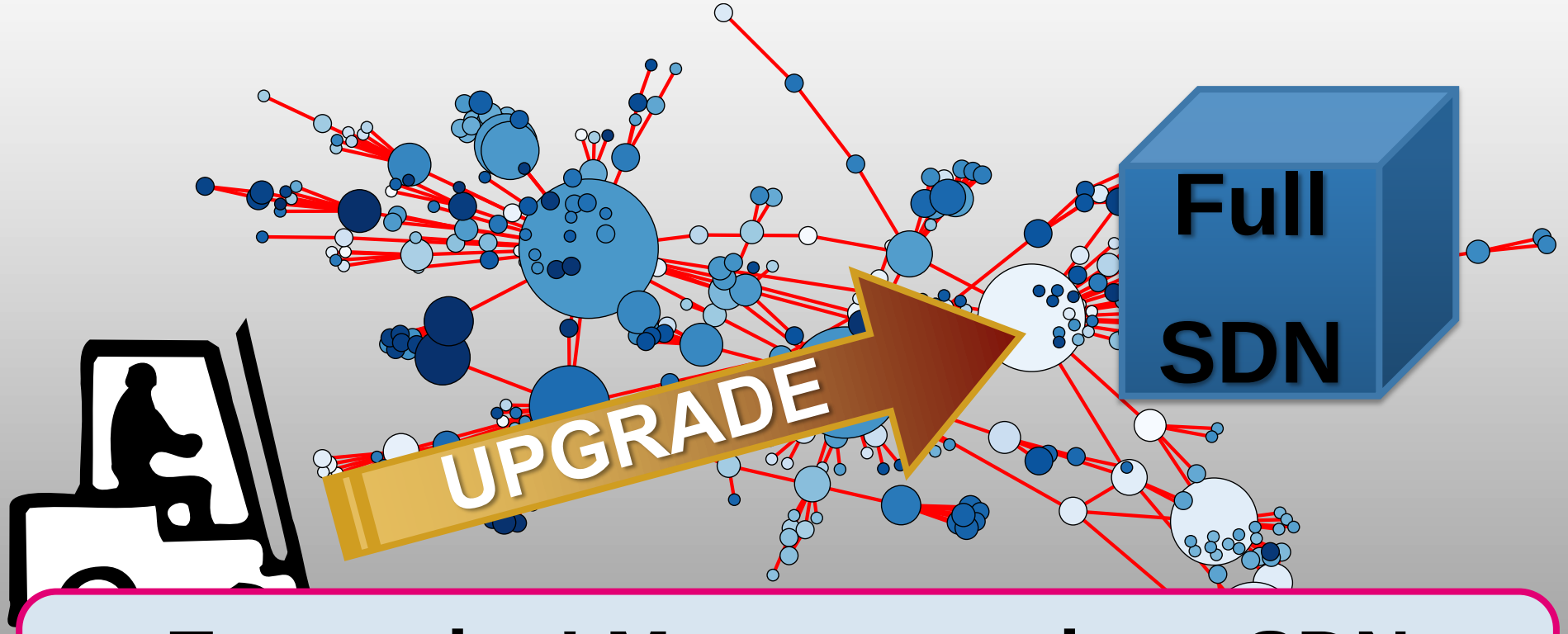


Control Plane

Packet Traces

Research Challenge 5: Hybrid Operation
Or: How to get there with my small budget?!

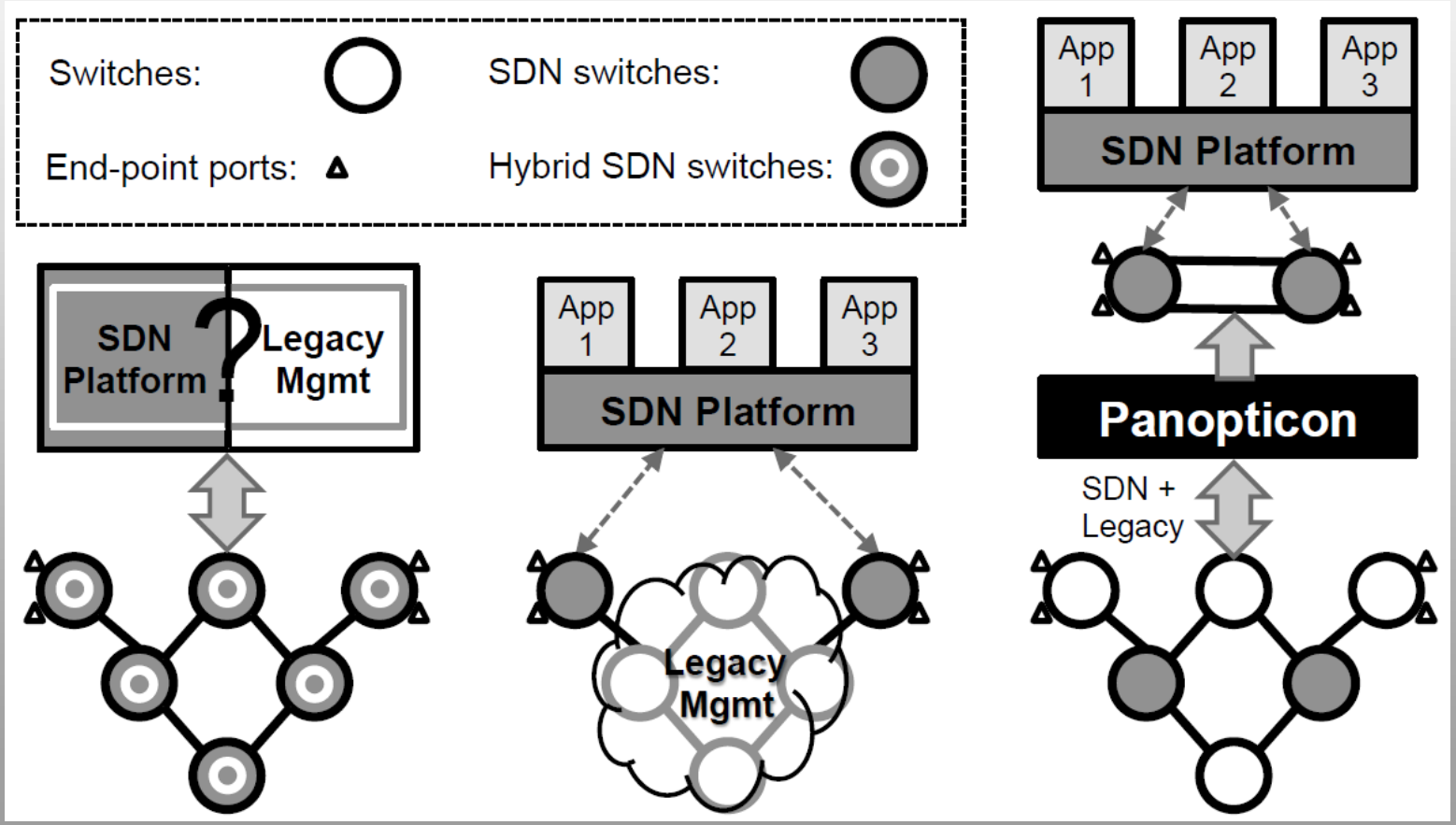
- Partial deployment and hybrid operation, e.g., Panopticon



Expensive! Must upgrade to SDN incrementally…

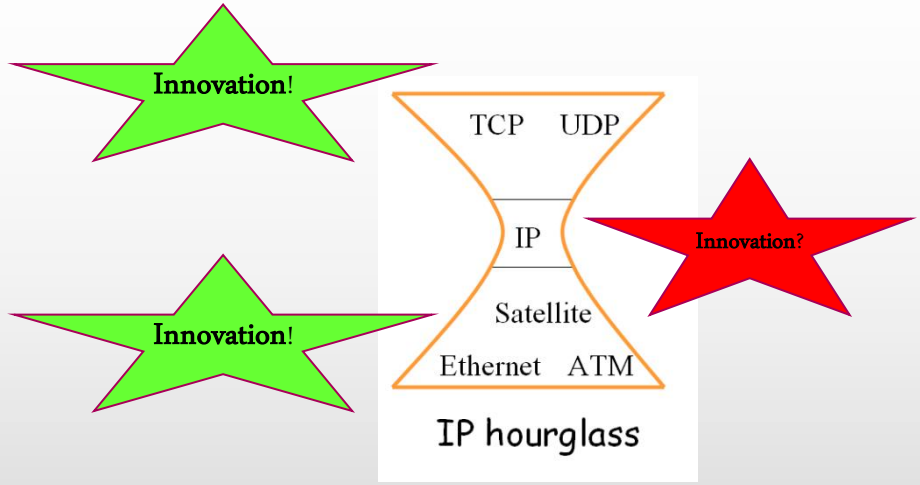
Research Challenge 5: Hybrid Operation
Or: How to get there with my small budget?!

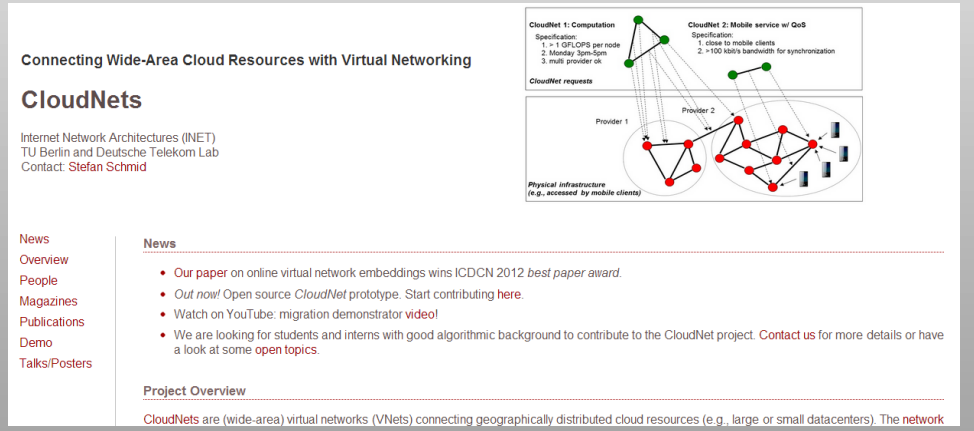
- Partial deployment and hybrid operation, e.g., Panopticon



Conclusion

- Virtualization is main innovation motor in Internet (e.g., IP layer, one-stop-service deployment, …)
- Trend: virtualized, software-operated, distributed
- First architectures emerging: open-source prototypes at TUB!
- Economically attractive: new services, resource provider at eye-level, new business roles (e.g., brokers)
- Talk to us for problems on distributed algorithms, self-organizing systems / self-assembly, prototype, ...





Anja Feldmann, Gregor Schaffrath, Marco Canini, Dan Levin, Carlo Fürst, Arne Ludwig, Lalith Suresh, Yvonne Anne Pignolet, Gilles Tredan, …

Obrigado! … and see you in Berlin?

Backup

As in Internet today:

Netflix, Google, World of Warcraft…

As in Internet today: Telekom, AT&T, …

+ resource control interface (bootstrapping etc.)

Roles in CloudNet Arch.

knows application

(offe… …he top)

Virtual Network Operator (VNO)

(operates CloudNet, Layer 3+, triggers migration)

Virtual Networ… Provider (VNP)

(resource broke… …iles resources)

Physical Infra… …e Provider (PIP)

knows network (uses resources at PoPs!)